U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-266 824

Tracking Pollutants from a Distance

Environmental Monitoring and Support Lab, Las Vegas, Nev

1977

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/J-77-007	2. JOURNAL ARTICLE	3. PB 266 824
4. TITLE AND SUBTITLE: TRACKING POLLUTANTS FROM A DISTANCE		5. REPORT DATE
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): S. H. Melfi, J. D. Koutsandreas, J. Moran		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Environmental Monitoring and Support Laboratory Office of Research and Development U.S. Environmental Protection Agency Las Vegas, Nevada 89114		10. PROGRAM ELEMENT NO. 1HD620 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: U.S. Environmental Protection Agency--Las Vegas, NV Office of Research and Development Environmental Monitoring and Support Laboratory Las Vegas, Nevada 89114		13. TYPE OF REPORT AND PERIOD COVERED: Journal article 14. SPONSORING AGENCY CODE: EPA/600/07

15. SUPPLEMENTARY NOTES
Published in Environmental Science & Technology 11:1, pp 36-38, Jan. 1977
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16. ABSTRACT

Remote sensing, "monitoring at a distance," is a new technique that the U.S. Environmental Protection Agency (EPA) is investigating and selectively applying to track environmental pollutants. The EPA is charged with reducing pollution to acceptable levels in order to minimize adverse effects on human health and welfare.

To accomplish this complex task, EPA needs a variety of monitoring techniques that provide accurate, precise, and legally defensible data. One powerful tool in this arsenal is remote sensing.

An obvious advantage of remote sensing is its perspective; it allows us to back away and look at the whole picture all at once. Remote sensing also offers another important advantage over more conventional monitoring techniques: it is cost-effective. This is an especially important consideration because it is unlikely that EPA will ever have the resources necessary to perform all the monitoring that is required.

This paper describes the remote sensing program in the Agency's Office of Research and Development. The program is divided into two major activities: first, it provides operational remote sensing support to the rest of the Agency, and second, it is developing advanced remote sensing techniques to meet the critical monitoring needs of the Agency.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Aerial Photography Remote Sensing Monitors Lasers		14E 20E,F

18. DISTRIBUTION STATEMENT: RELEASE TO PUBLIC

REPRODUCED BY NATIONAL TECHNICAL INFORMATION SERVICE U.S. DEPARTMENT OF COMMERCE SPRINGFIELD, VA. 22161

19. SECURITY CLASS (This Report): UNCLASSIFIED
21. NO. OF PAGES: 6
20. SECURITY CLASS (This page): UNCLASSIFIED
22. PRICE: PC A02/MF A01

EPA Form 2220-1 (9-73)

ATTACHMENT TO EPA FORM 5320-2

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ENVIRONMENTAL SCIENCE & TECHNOLOGY, Vol. 11, No. 1, 36-38, January 1977
EPA-600/J-77-007
JOURNAL ARTICLE

Tracking pollutants from a distance

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New remote sensing methods, used to gather legally defensible data, are but one valuable set of tools EPA can use to meet its monitoring responsibilities

Remote sensing, "monitoring at a distance," is a new technique that the U.S. Environmental Protection Agency (EPA) is investigating and selectively applying to track environmental pollutants. Instrument-packed satellites and aircraft used to observe the surface of the earth and its atmosphere are but examples of remote sensing. A view of the earth from space uniquely demonstrates that the environment surrounding the earth is a closed system of limited dimensions that must be protected. Environmental pollution may be localized, but there also are examples of pollution problems that are global in extent. One example is the potential reduction of the protective ozone layer surrounding the earth.

The EPA is charged with reducing pollution to acceptable levels in order to minimize adverse effects on human health and welfare. This mandate requires, first, that EPA locate and measure the sources of environmental pollution. Then that it:

- trace the transport or movement of pollutants from their source through the environment
- monitor the ambient concentrations of pollutants that humans or other critical receptors are exposed to
- determine the dose that the human population receives as a result of this exposure
- assess the effects that this dose has on all critical receptors
- measure the effectiveness of controls placed on the original sources of pollution.

Earth-reflected differential absorption systems can be used for . . .

- oxidant transport studies (O_3)
- plume inventories (SO_2)
- plant siting studies (trace gas)
- model verification

. . . while airborne LIDAR systems can . . .

- measure inversion layer height
- determine plume dimensions
- position other monitoring platforms
- support model efforts

. . . and laser fluorosensing can . . .

- characterize oil spills
- determine vegetation stress
- monitor selected water pollutants
- map chlorophyll
- be used in dye dispersion studies

To accomplish this complex task, EPA needs a variety of monitoring techniques that provide accurate, precise, and legally defensible data. One powerful tool in this arsenal is remote sensing.

An obvious advantage of remote sensing is its perspective; it allows us to back away and look at the whole picture all at once. Remote sensing also offers another important advantage over more conventional monitoring techniques: it is cost-effective. This is an especially important consideration because it is unlikely that EPA will ever have the resources necessary to perform all the monitoring that is required.

EPA's monitoring activities can be divided into four basic approaches: satellite monitoring, aerial sensing, continuous monitoring at fixed sites, and grab sampling. Of these four approaches, satellite monitoring offers the best perspective and is potentially the most cost-effective. But satellite measurements are lowest in resolution and their accuracy and precision may not be sufficient to address many monitoring problems.

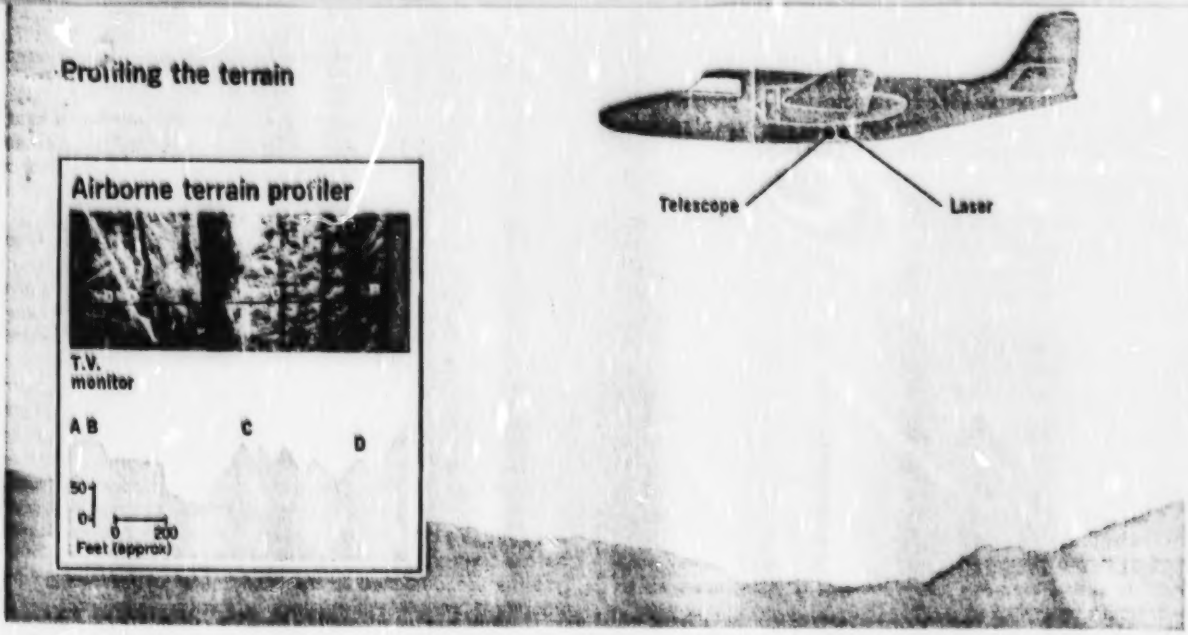
Aerial sensing provides somewhat less perspective than a satellite system, but resolution is better. Continuous-monitoring stations located on the ground have even better accuracy and precision, but they can only monitor one point. To get any perspective requires a network of many critically placed monitoring stations.

The most accurate and precise way to measure pollutants is to collect samples in the environment and take them back to the laboratory where sophisticated equipment can be used for detailed analysis. However, this grab-sampling (ground-truth) technique provides very little perspective and is extremely labor-intensive.

These four monitoring approaches—satellite monitoring, aerial sensing, continuous-monitoring stations, and grab sampling—offer decreasing perspective with increasing accuracy and precision. They also represent increasing costs.

Grab sampling. *This man is gathering ground-truth data*

Profiling the terrain



Choosing the method

Obviously, EPA must determine the degree of perspective, accuracy and precision needed for a given assignment and then select the least costly approach or combination of approaches that meets these requirements.

For example, if EPA receives a complaint that a specific plant is discharging pollutants into a waterway, the agency can collect water samples near the discharge and analyze them in a laboratory. In this case, grab sampling is the best way to find out what's going on at that one location—and it's probably the most cost-effective. On the other hand, if the problem is to identify all the sources of pollution in a given river, grab sampling would be time consuming and prohibitively expensive. And, with grab sampling, it would be easy to miss important sources of poilution.

With remote sensing, EPA could fly over the area and provide a reasonably accurate assessment of the source of pollution within a couple of days. If more precise measurements were required, the agency could then collect samples at the pollution sources that were spotted from the air.

The Remote Sensing Program in the agency's Office of Research and Development is divided into two major activities: first, it provides operational remote-sensing technical support to the rest of the agency and, secondly, it is developing advanced remote-sensing techniques to meet the critical monitoring needs of the agency.

Examples of the operational Remote Sensing Program abound. For instance, on most major oil spills on the nation's waters, EPA cooperates with the U.S. Coast Guard by providing aerial remote sensing of the spill location. Aerial remote-sensing photography is invaluable for locating concentrations of oil and for providing basic information to the U.S. Coast Guard for dispatching clean-up crews.

Another example of operational-remote-sensing is the use of heat-sensing instrumentation on-board an aircraft to image, detect and monitor increases in water temperature resulting from the discharge of heated water from power plants and other industries. Usually these discharges are not visible to the naked eye and do not show up on photographs. But heat-sensitive instrumentation can measure the distribution of the warm water and the data collected can also be used to construct isothermal or constant temperature maps of the receiving waters so that a detailed assessment of the impact of these hot discharges can be performed.

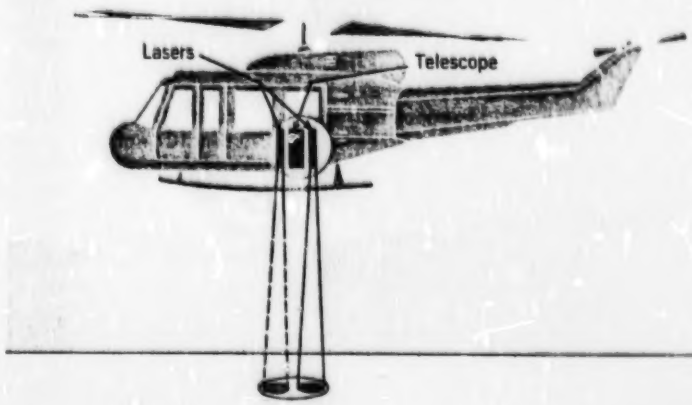
A third example of operational-remote-sensing involves the use of both photography and heat-sensing instrumentation to locate and document points of pollution discharged to our nation's waters. Recent field work has demonstrated that 98% of water pollution discharge points are detectable either because of a change in color, which can be monitored by photography, or a change in temperature, which can be measured by the heat-sensing instrumentation.

Operational-remote-sensing also can be used to monitor the land mass of the U.S. For example, aerial photography and satellite imagery can be used to study the way the land is being used in order to locate non-point sources of pollution that affect the quality of our nation's waters. It is also possible to document the extent of landfills and assess the pollutants that result from landfill activities. And, by studying the quantity and type of housing in a given area, aerial photographs can be used to estimate the population density around freeways to determine how many people might be affected by localized exposure to automobile pollution, or around airports, where noise often is an important environmental consideration.

Aerial-remote-sensing has been used over strip-mining areas in the western U.S. By using photography and false-color infrared photography it is possible to determine whether the strip mining is being performed with minimum impact to the environment and, also, if the strip-mining companies are returning the land to a useful state by revegetating after the mining operation.

EPA has also used a unique instrument on-board aircraft in strip-mining areas called the "laser terrain profiler." This laser system can very accurately measure ground contour, and it is used to determine whether strip-mined land has been properly recontoured.

Measuring atmospheric inversion height by LIDAR

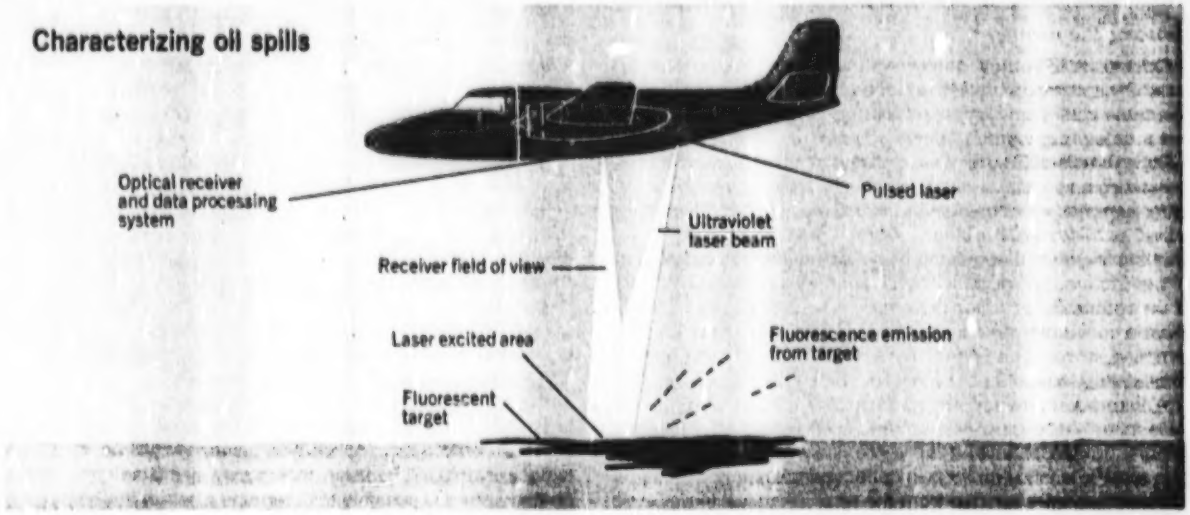


How operational-remote-sensing is used

The results of the operational-remote-sensing program are provided to other divisions of the agency in the form of reports or as remote-sensing imagery and interpretive results on computer-compatible cards. The latter format permits the ready retrieval of information stored in computer data banks.

The development activity within the remote-sensing program includes image acquisition and interpretation systems, and environmental laser-probing systems. EPA is developing an aerial photographic technique to measure the opacity or density of an atmospheric "smoke plume." The intensity of the shadow of the plume on the photograph is compared to the intensity of the shadow of an opaque, or solid, object.

Another technique that EPA is developing in cooperation with the National Aeronautics and Space Administration uses a multi-spectral scanner. This instrument can measure reflectance energy from the surface of the earth—either the land mass or the water. The information obtained is digitally recorded and can be processed cost-effectively by using computer systems. Presently, the system automatically provides imagery categorized by land-use type and, for the future, EPA is developing methods to use the instruments for monitoring various water quality parameters.



In a development mode

The laser techniques EPA is developing for use from aircraft are designed to be pollutant-specific. Included within this development activity is the LIDAR (Light Detection And Ranging) system. It is similar in concept to a radar system except that LIDAR uses a pulse of laser energy. The laser is fired down toward the ground. As it moves through the atmosphere, it is scattered by the particles in the air. A portion of the scattered energy is collected by a telescope on-board the aircraft. The data can be displayed on a cathode-ray tube to give an immediate picture of particle layering below the aircraft. The system is used to measure atmospheric plume dimensions and trajectories and, most importantly, to measure atmospheric inversion height, especially during air pollution episodes.

A second laser technique under development is called the differential absorption LIDAR. This technique uses pulses from two lasers that are pointed toward the ground. One of the beams is adjusted to a wave length that is absorbed by the specific gas being measured. The second beam is adjusted to a frequency that is not strongly absorbed by this gas. Both beams propagate down to the ground and are reflected back to the aircraft. A telescope on-board collects the reflected energy. A continuous comparison of the reflected energy from both beams provides a measure of the molecular concentration of the absorbing gas between the aircraft and the ground. The first gas to be measured in this manner is ozone. A future system will be designed to measure sulfur dioxide.

One application of the ozone instrument will be to study long-range transport of oxidants from urban or industrial areas. Another obvious application would be the measurement of pollutant gases in atmospheric plumes from various industrial sources.

A third laser technique under development is called laser fluorescence. In the presence of certain frequencies of blue or ultraviolet light, many substances fluoresce, that is, they give off light. In this method, an ultraviolet laser is directed toward the surface of the earth. Again, a telescope on-board the aircraft collects the color-shifted energy called fluorescence that is emitted from the target that the laser beam strikes. In many cases the color and intensity of the fluorescence is characteristic of the molecule that is fluorescing. Laser fluorescence can be used to measure water pollution by monitoring such things as oil on the surface of the water, dissolved organics in water, and the location of algal blooms. In addition, EPA is now investigating whether there is a unique fluorescent signature from vegetation that has been grown in the presence of air pollutants. All the laser systems are designed to be totally safe to persons on the ground.

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